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SQUIB DEVELOPMENT PROGRAM

REPORT

to

U. S. NAVAL WEAPONS LABORATORY
DAHLGREN, VIRGINIA

Contract N 178-8081

Second Quarterly Report

30 September 1962 To 31 December 1962

THE Bendix CORPORATION
SCINTILLA DIVISION
SIDNEY, NEW YORK, U.S.A.

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on

Squib Development Program

for the

U.S. Naval Weapons Laboratory
Dahlgren, Virginia

Contract N178-8081

Prepared By Rolland M. Purdy
Rolland M. Purdy, Sr. Project Engineer

Approved By Tullio Tognola
Tullio Tognola, Assistant Director of Engineering

The Bendix Corporation
SCINTILLA DIVISION
Sidney, New York
U.S.A.

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SECOND QUARTERLY REPORT

FOR

PERIOD ENDING DEC. 31, 1962

CONTRACT N178-8081

1.0 Introduction

1.1 This is the second of four quarterly technical progress reports covering the design and development of an electro-explosive device intended to be immune to stray radio-frequency energy. A spark gap bridged by a semi-conductive material is employed to accomplish this goal. The report deals with the investigations and tests conducted during the report period.

2.0 Summary

2.1 ~~Investigation in the field of semi-conducting materials has continued.~~ The prospect of obtaining a material which will limit firing energies to desired values, ~~which~~ will maintain stability after repeated firings, and ~~which~~ will also possess desirable manufacturing characteristics seems reasonable. Spark testing has been conducted ~~at Scintilla~~ to determine the correlation between the energy to rupture the diaphragm and combinations of electrode to electrode resistance, diaphragm thickness, and spark chamber volume. One hundred ninety squibs were shipped to Flare-Northern Division of Atlantic Research Corp. for loading and firing using various explosive mixtures. Results ~~These tests~~ are reported herein. Future work is also indicated.

3.0 Detailed Report

3.1 Investigation of Semi-conducting Materials

3.1.1 The First Quarterly Report covered the initial development of a melt type semi-conductor which would act as a ceramic to metal sealer and as a high impedance semi-conductor material in an electro-explosive device. A major purpose of the work reported herein has been to perfect the melt techniques so as to prevent drainage of the semi-conductor through the holes containing the electrode lead wires. Other purposes of this work were to adjust the melt composition so as to eliminate cracking of the ceramic cup during the cooling cycle, and to obtain an electrical resistance compatible with the functioning requirements of the electro-explosive device.

3.1.2 As a result of this work, the following may be concluded:

a. A redesign of the ceramic cup and the use of Kovar electrodes with a high temperature glass seal effectively seals the opening and prevents drainage of the melt past the electrode lead wires.

b. The use of aluminum oxide or magnesium oxide in the melt stops the cracking of the ceramic cup.

c. The use of magnesium oxide apparently increases the thermal conductivity and thus dissipates the heat build-up from a 200 VDC current applied to the electrode gap.

d. Composition 1037-6 is the best material tested to date on the basis of the evaluation conducted at Scintilla.

3.1.3 The work leading to the foregoing conclusions will be discussed under subheadings as follows:

Silicon Carbide and Molybdenum Disilicide Bodies (Para. 3.1.4)

Manufacture of Gap Assemblies - Melt 1030-1 (Para. 3.1.5)

Al_2O_3 Additions for Expansion and Resistance Control (Para. 3.1.6)

Redesign of Ceramic Cup for Glass Sealing of Electrodes (Para. 3.1.7)

Substitution of MgO for Al_2O_3 to Improve Thermal Conductivity (Para. 3.1.8)

Lithium Manganite Additions (Para. 3.1.9)

3.1.4 Silicon Carbide and Molybdenum Disilicide Bodies

3.1.4.1 Silicon carbide and molybdenum disilicide are two fairly common conductors of electricity which are resistant to high temperatures. It was thought possible that if dispersed in a glass so that the conductive particles formed the continuous phase, a usable semi-conductor might be formed. Table 1 shows the results of blending silicon carbide and Alsilox (lead silicate glass).

TABLE 1

Series 1027	Weight Percent		
	-1	-2	-3
SiC (400 mesh)	90	80	70
Lead Silicate (200 mesh)	10	20	30
	100	100	100
Firing Temp. °F			
1500	*No good	No good	No good
1700	No good	No good	No good
1800	No good	No good	No good

3.1.4.2 A new series of melts were prepared as shown in Table 2 using a mixture of molybdenum disilicide, silicon carbide, and lead borate glass. It was hoped to increase the conductivity and decrease the viscosity of the melt.

TABLE 2

Series 1029	Weight Percent -1	-2	-3	-4	-5
$MoSi_2$	8.3	16.7	25.0	33.4	41.7
SiC	75.0	66.7	58.3	50.0	41.6
$Pb(BO_2)_2H_2O$	16.7	16.6	16.7	16.6	16.7
	100.0	100.0	100.0	100.0	100.0

Firing Temp. °F	Ohms Resistance -1	-3	-5
1600	∞	∞	∞
1700	4 megohms	5-10 megohms	∞
1800	10,000 ohms	100,000 ohms	5 megohms

The 1029 series sintered, shrunk into hard pellets, but did not melt enough to flow.

3.1.4.3 A new series, 1030, was developed in which the glass was increased to about 50% by weight. The results were not encouraging because severe bubbling and bloating occurred during the melting process.

3.1.4.4 Another series, 1031, was prepared in which a high temperature Pyrex glass, Corning #7052, was substituted for the lead borate. Sample buttons were pressed and fired - this time in a hydrogen atmosphere to inhibit decomposition of the conductive particles. The button bloated and further work with these materials was discontinued.

3.1.4.5 It became apparent from the results of these series that if the conductive phase was continuous, the resistance could be varied but the melt condition could not be obtained.* When sufficient glass was present to form a melt, the resistance was infinite and the glass bloated from internal gas pressure.

3.1.5 Manufacture of Gap Assemblies - Melt 1030-11

3.1.5.1 The 1030-11 semi-conductor material was produced by grinding in a small porcelain mortar until thoroughly blended. The material was then placed in an alumina crucible and melted in an electric furnace at 2100°F. When the material was completely molten, the crucible was removed from the furnace and the contents poured into cold water. The material was then dried and crushed in a diamond mortar to pass a 16 mesh sieve.

3.1.5.2 Squib assemblies were produced by first inserting and firmly pressing the electrode into the ceramic cup. The cavity was then filled with the granular 1030-11 semi-conductor and fired in an electric furnace at 2000°F for 5 min. Units showing voids were refilled and fired again. The assemblies were ground on a liquid cooled diamond wheel bench grinder to open the gap between the electrodes and produce the required resistance.

3.1.5.3 Cracking of the ceramic cup and leaking of the semi-conductor was in evidence in all of these units, but as this did not effect the electrical properties these units were tested and evaluated.

3.1.6 Al_2O_3 Additions for Expansion and Resistance Control.

3.1.6.1 Microscopic examination of cracked ignitor units indicated that the thermal expansion of the semi-conductor was lower than the alumina ceramic. As a result of this, the tension stresses set up in the ceramic when cooling from fusing in the semi-conductor were just enough to cause cracking of the ceramic. To increase the thermal expansion of the semi-conductor, fused Al_2O_3 was added to the mixture.

3.1.6.2 Test results also indicated that to successfully pass the 220 volt test a higher resistance was necessary. It was hoped that additions of nonconductive Al_2O_3 would also increase the resistance of the semi-conductive mix.

TABLE 3

Composition (Wgt. Percent)					Button Fusing Temperature °F			
	Cu_2O	Fe_2O_3	Al_2O_3	ZnO	1875	1900	2000	2100
1032-6	79.8	15.2	5 (Alon-c)	--	No melt	No melt	Start	Melt gassy
-7	75.6	14.4	10 (Alon-c)	--	"	"	"	10K
-8	71.4	13.6	15 (Alon-c)	--	"	"	"	"
					1950		2000	2050
1033-1	68.7	13.1	9.1 (200 Mesh)	9.1	Good 160K		Good 70K	Good 100K
-2	65.7	12.5	13.1	8.7	Fair 140K		Fair 50K	Good 70K
-3	63.0	12.0	16.7	8.3	Poor 120K		Slight 80K	Fair 60K
-4	60.5	11.5	20.0	8.0	Slight 180K		Slight 40K	Slight 60K
-5	58.2	11.0	23.1	7.7	None 140K		Slight 20K	Very slight 20K
					Assembly Fusing -2000°F			
1041-1	75.6	14.4	5	5	20-30K			
-2	71.4	13.6	5	10	20-30K			
-3	71.4	13.6	10	5	20-30K			
-4	67.4	12.6	5	15	148K			
-5	63.0	12.0	5	20	200K			
-6	58.8	11.2	5	25	150K			

3.1.6.3 The three 1032 mixes were made with Cabot Alon-c alumina. This was a very fine colloidal alumina with high bulk volume. Pellets were pressed using camphor as a binder. Pellets were fired as indicated in Table 3. The resistance of these mixtures was very low and considerable gassing took place which produced a very porous melt. None of the mixes were considered promising and no assemblies were made with these materials.

3.1.6.4 It was apparent from these mixes that the fine alumina would not increase the resistance sufficiently and produce a good melt. As a result of this, the 1033 and 1041 mixtures were made using a coarse (220 mesh) alumina in combination with zinc oxide in the basic copper oxide - iron oxide mixtures. Buttons were pressed out of the 1033 mixes with camphor binder and fired five minutes at the temperatures indicated in Table 3.

3.1.6.5 Squib assemblies were made using the 1041 mixtures in Table 3. An assembly was also made using the 1033-1 mixture. 1041-1, -2, -3 were in the 20K to 30K range and considered too low. Assemblies 1033-1, 1041-4, -5, -6 with resistances of 110K, 148K, 200K and 150K respectively, were tested electrically.

3.1.6.6 No cracking was observed in any of these squib assemblies. Assembly 1033-1 passed all electrical tests including the 220 volt test but the electrodes loosened as a result of the 20KV pulsing test. Assembly 1041-6 passed all electrical tests including 15 minutes at 200 volts. When retested at 220 volts, this assembly failed after 12 minutes.

3.1.6.7 As a result of these tests, there appeared to be no electrical problems with the exception of the 220 volt test. Three more 1033-1 and four 1041-6 assemblies were made. These assemblies were checked only on the 220 volt test with an arbitrary 5 minute test time. None of the 1033-1 and only one 1041-6 assemblies passed this test.

3.1.7 Redesign of Ceramic Cup for Glass Sealing of Electrodes

3.1.7.1 Considerable difficulty was experienced when producing squib assemblies in keeping the semi-conductive melt from leaking out of the ceramic cup around the electrode pins. Sealing the electrode pins into the ceramic cup appeared to be the best approach to this problem. A small counterbore was made in the base of the ceramic cup to provide a cavity to contain the sealing glass and still maintain a flat base surface. A high temperature glaze previously developed to fit the ceramic and maturing at 2550^{o}F was chosen as the sealing medium. After pressing the electrode into position in the ceramic cup, a small amount of glaze slip was introduced into the ceramic counterbore by the use of a small syringe and the assembly vibrated to aid the flow of the glaze slip. The assemblies were placed on fixtures and oven dried.

3.1.7.2 To insure a better thermal expansion match between the ceramic, the electrode, and the glass, the electrode material was changed to Kovar instead of the nichrome previously used. Fusing of the glass was carried out in a wet hydrogen atmosphere to prevent excessive oxidation of the Kovar electrodes. This was done at 2550^{o}F with a fifteen minute soak at temperature. After this assembly method was adopted, no difficulty was experienced with semi-conductor leakage.

3.1.8 Substitution of MgO for Al_2O_3 to Improve Thermal Conductivity.

3.1.8.1 Because the 220 volt test was the chief or only cause of failure of the squib assemblies tested, all effort was concentrated on this problem. Semi-conductive mixes were made substituting magnesium oxide for aluminum oxide as shown in Table 4. This was done to take advantage of the high thermal conductivity of magnesium oxide and to dissipate the heat more rapidly from the semi-conductor. General Electric E-214 magnesium oxide was used. This is a coarse material with .5% maximum on 40 mesh and 7% maximum through 325 mesh.

TABLE 4

	Composition (Wgt. Percent)				Melt Temperatures °F (Buttons)					
					1950		2000		2050	
	Cu_2O	Fe_2O_3	ZnO	MgO	Melt	Ohms	Melt	Ohms	Melt	Ohms
1034-1	68.7	13.1	9.1	9.1	Good	150K	Good	180K	Good	200K
-2	65.7	12.5	8.7	13.1	-	-	-	-	-	-
-3	63.0	12.0	8.3	16.7	Poor	200K	Fair	200K	Good	200K
-4	60.5	11.5	8.0	20.0	-	-	-	-	-	-
-5	58.2	11.0	7.7	23.1	Slight	180K	Slight	190K	Good	200K
1041-6 MgO	58.8	11.2	25.0	5						
				MgO, fine, -325						
1035-1	68.7	13.1	9.1	9.1	-	-	Poor	100K	Fair	90K
-2	65.7	12.5	8.7	13.1	-	-	-	-	-	-
-3	63.0	12.0	8.3	16.7	-	-	Poor	180K	Poor	100K
-4	60.5	11.5	8.0	20.0	-	-	-	-	-	-
-5	58.2	11.0	7.7	23.1	-	-	None	500K	Poor	190K

3.1.8.2 Very little difference in the resistance of these mixes could be detected although melting was better with the lower MgO contents. A 50 gram batch of 1034-1 composition was made and fritted as before. Two squib assemblies were made by firing at 2000°F for 5 min. and 15 min. Both assemblies were too low in resistance (6K and 10K) and were very gassy, causing numerous voids in the semi-conductors. No cracks were evident in these assemblies.

3.1.8.3 One assembly made with 1041-MgO6 was tested at 220 volts and appeared to be superior to the other compositions. Seven more assemblies were made and tested with and without heat sinks.

3.1.8.4 The 1035 compositions duplicated the 1034 compositions with the substitution of -325 mesh MgO for the coarse GE-214 MgO. These compositions were very poor physically due to bloating and gassing. No assemblies were made with these compositions.

3.1.8.5 Three other magnesium oxide mixtures were made. These contained very high percentages of magnesium oxide and were intended to sinter without shrinkage or flow in the ceramic cup. These compositions are given in Tabel 5.

TABLE 5

	Cu_2O	Fe_2O_3	MgO	Buttons 2000°F Ohms	Buttons 2100°F Ohms
1037-4	16.8	3.2	80		
-5	25.2	4.8	70	5 MEG	
-6	33.6	6.4	60	2 MEG	500K

Squib assemblies made with these mixes had very high resistances, over 650K. These assemblies were tested and passed the 220 volt test but would not fire.

3.1.9 Lithium Manganite Additions

3.1.9.1 In combination with the magnesium oxide, several compositions were made with additions of lithium manganite as shown in Table 6. Both lithium and manganese are commonly used to "dope" semi-conductors when a higher resistance is wanted. Copper oxide has an inherently high negative temperature coefficient of resistance. It was hoped that lithium manganite additions would increase the resistance of the semi-conductor thus decreasing the flow of current and decreasing the temperature rise. (Table 6)

TABLE 6

	Cu_2O	Fe_2O_3	MgO	$LiMnO_3$	Buttons Temperature °F 2000 Melt	2000 Ohms	2050 Melt	2050 Ohms
1036-1	71.4	13.6	10	5	Good	100K	Good	100K
-2	67.2	12.8	10	10	Fair	200K	Good	180K
-3	63.0	12.0	10	15	Poor	200K	Fair	220K
-4	58.8	11.2	10	20	Poor	200K	Fair	250K
1040-1	61.8	11.8	5.3	21	Slight	250K	Slight	250K
-2	65.4	12.4	0	22.2	Slight	250K	Slight	250K

3.1.10 Bismuth Oxide

3.1.10.1 To decrease the viscosity of the 1036 compositions, bismuth oxide, a low melting oxide, was introduced into the mix as shown in Table 7.

TABLE 7

	Cu_2O	Fe_2O_3	MgO	$LiMnO_3$	Bi_2O_3	Buttons Temperature °F			
						1950		2000	
						Melt	Ohms	Melt	Ohms
1037-1	63	12	10	10	5	Slight	400K	Fair	300K
-2	58.8	11.2	10	10	10	Good	450K	Good	800K
-3	54.6	10.4	10	10	15	Good	500K	Good	1 Meg

The resistance of these mixtures appeared to be in the range required but assemblies made with the 1037-2 composition failed the 220 volt test.

3.1.11 Electrode Redesign

3.1.11.1 In the course of investigating semi-conductive compositions, it was found that button fusion tests of these mixes were almost impossible to correlate to the results obtained in actual squib assemblies. This necessitated the making of squib assemblies for each mixture investigated, which increased the quantities of electrodes consumed. Because the original electrode design was slow and difficult to make, it was decided to manufacture a die to completely form the electrodes without further machining. Because the new design electrode was of a different configuration, squib assemblies were made of several semi-conductor compositions previously tested. In general, all assemblies had lower resistances with the new type electrodes than those previously made with the original electrodes. Very few compositions appeared to have high enough resistances to pass the 220 volt test. The 1037 compositions were closest to the resistance values sought.

3.1.11.2 Although the resistance is inversely proportional to the thickness of the semi-conductor and can be varied to some extent by the grinding operation, control was not as good as desired.

3.1.11.3 One 1037-6 assembly was made and passed all electrical tests. This was followed by a group of six assemblies made in the same way. The test results of these assemblies warranted the making of 41 more assemblies.

Several squib assemblies were made with these mixes. All of the mixes were very viscous when melted and did not flow and fill the ceramic cups. These assemblies all failed the 220 volt test.

3.2 Electrical Testing at Scintilla

3.2.1 Type of Tests

The following test routine was followed on all parts:

1. Resistance measurement

2. Gap measurement

3. Pulse test to determine minimum no-fire point.

4. 36 volt D.C. test

5. 220 volt 60 cycle test

6. 20 KV - 20 uuf capacitor pulse test

During the latter three tests no part should fire, ie, produce a visible spark across the gap. These tests were conducted on squib bodies having various conductive mixtures bridging the gap.

3.2.2 Mixture 1030-11 (zinc, iron and copper oxides).

3.2.2.1. Table 8 shows the results of preliminary testing. At this point there seems to be no correlation between resistance and gap spacing. For a time, therefore, it was decided to use but one gap spacing - .040".

3.2.2.2 The 36 volt DC test posed no problems - no squibs fired when subjected to this energy.

3.2.2.3 The 220 VAC proved too severe for this 1030-11 material. Approximately 170 - 190 volts could be tolerated but 220 caused the squib body to become red hot - and an arc appeared across the gap.

3.2.2.4 The 20 KV - 20 uuf test disclosed sparks across the gap. These sparks, however, wer not the vigorous discharges ordinarily considered a "firing". Inclusion in a complete squib will determine whether or not this is sufficient to rupture the diaphragm.

3.2.3 Mixture 1033-1 (same as 1030-11 with aluminum oxide added.)

This mixture produced results similar to that of 1030-11 in all tests except the 220 VAC. In this test, the squib body reached what appeared to be a stabilizing temperature of 250°F in 6-8 minutes. After the squib returned to room temperature, the resistance was found to have returned to its original value.

3.2.4 Mixture 1041 M60

3.2.4.1 This type of mix produced a squib having a resistance of 400-600 K ohms. It can take the 220 VAC test - both 60 and 400 cycles - for approximately 2 minutes with no ill effects. This same unit, when encased in an aluminum heat sink having dimensions of .360" x .291" ID with .060" walls, can tolerate 220 volts for an indefinite length of time.

3.2.4.2 During this testing, it was found that this material is temperature sensitive. The 400 K ohms at room temperature drops to 200 K ohms at 150°F and rises to 4000 K ohms at 0°F. Other semi-conducting materials will be checked to determine whether or not this characteristic is typical of semi-conducting materials.

3.2.5 Mixture type 1037-6

This mixture is composed of 40% FE_2O_3 and Cu_2O and 60% MgO. 41 squibs having this material as a gap bridging agent were tested as follows:

3.2.5.1 Resistance - 300K to 600K ohms

3.2.5.2 Pulse test -

All squibs were given 5 pulses at 20KV - 20 uuf. Resistance was measured after last pulse. A 5% to 10% decrease in resistance occured, but after a few minutes the resistance returned to its original value.

3.2.5.3 Spark Test -

Each squib was tested at 2 KV to determine energy required to produce a visible spark across the gap.

35 squibs showed a spark at .1 joule
1 did not fire up to 2.6 KV
1 fired at 2.6 KV
4 fired at energies from .2 joule to .5 joule

These same squibs were also tested at 500 volts, 1 uf. No sparking occured.

3.2.5.4 36 Volt DC test -

Approximately 12 squibs were subjected to this test with no malfunction.

3.2.5.5 220 volts, 60 and 400 cycle test -

Eleven squibs were tested at 220 volts - 60 cycles and fourteen pieces tested at 220 volts - 400 cycles. One squib out of each of these groups failed after 20-25 minutes. No heat sink was used. Had there been a heat sink, the two failed units would have, in all probability, survived.

3.2.5.6 Bruceton test -

Twenty-six squibs with resistances ranging from 290K to 700K ohms were assembled in phenolic shells with a .0005" thick diaphragm. These same pieces were then supplied with a .001" thick diaphragm. Test results were as follows:

a. <u>.0005 diaphragm</u>

$\bar{x}$ (50% fire point = .25 joule
Minimum no fire point = .05 joule
Maximum all fire point = .45 joule

b. <u>.001 diaphragm</u>

$\bar{x}$ = .68 joule
Minimum fire point = .25 joule
Maximum all fire point = 1.1 joule

3.2.5.7 Spark tests at + 165°F, 0°F, -65°F and -100°F. This test was made to determine changes, if any, in electrical characteristics with varying ambient temperatures. Results of these tests showed that:

a. At +165°F no change in behavior was observed even though the electrode to electrode resistance decreased to one half its room temperature value.

b. At 0°F, -65°F and -100°F, the electrical characteristics did change however, the required energy and/or voltage increasing by approximately 4 times.

3.2.5.8 Spark testing with a diaphragm at temperatures of paragraph 3.2.5.7. Nineteen squibs were supplied with .001" thick diaphragms and subjected to the following tests using values obtained from tests in paragraph 3.2.5.6.

a. -65°F

1. 5 pieces at .25 joule no fire point
no squibs fired.

2. 4 pieces at 1.1 joule - all fire point
3 fire - 1 no fire

b. +165°F

1. 5 pieces at .25 joule no fire point
no squibs fired.

2. 5 pieces at 1.1 joule - all fire point.
All fired.

3.2.5.9 Parts tested for shipment to Flare - Northern -

190 squibs were Bruceton tested and divided into the following categories prior to shipment.

a. Two diaphragm thicknesses - .0005" and .001"

b. Two spark chamber volumes - .006 cm^3 and .004 cm^3

c. Two resistance ranges - 390 ohms to 100 K ohms and 100 K ohms to 3 megohms.

3.2.5.10 The results of these Bruceton tests are as follows:

a. .001" diaphragm - .006 cm^3 volume

1. 30 piece Bruceton - 100K to 3 megohms resistance

$\bar{x}$ (50% fire point) = .77 joules
S (Standard deviation) = .20 joules

2. 21 piece Bruceton 100K to 390K ohm resistance

$\bar{x}$ = .72 joules
s = .12 joules

b. .0005" diaphragm - .006 cm^3 volume

1. 25 piece Bruceton - 100K to 3 megohms resistance

$\bar{x}$ = .33 joules
s = .08 joules

2. 24 piece Bruceton - 100K to 390K ohms resistance

$\bar{x}$ = .29 joules
s = .045 joules

c. .0005" diaphragm - .004 cm^3 volume

1. 24 pice Bruceton - 100K to 390K ohms resistance

$\bar{x}$ = .22 joules
s = .04 joules

See probability curves, figures 1 through 5

3.3 Firing Tests at Flare-Northern Division Atlantic Research Corp.

3.3.1 During the first tests a relatively sensitive explosive mixture was used (barium - zirconium). In view of the fact that this mix deteriorates rapidly at 350° - 400°F, other mixes were tried. A copper - titanium mix, capable of withstanding 600°F was the first of the higher temperature formulations tried. This not only did not deteriorate at 600°F but also did not fire at the desired input.

3.3.2 Since this new powder is not as sensitive as the lower temperature powder, an effort was made to counteract this insensitivity by intensifying the effect of the spark. This was accomplished by decreasing the volume of the spark chamber to .0014 cm^3. Foil diaphragms were reduced in thickness to .00025". The same copper - titanium mix was used. However, this time, it was mixed with a Melaqua binder, cured at 135°F, and granulated into a finely divided powder. This results in a more sensitive mixture. A scanning test, made on 14 squibs loaded with this mixture, indicated an $\bar{x}$ of .5 - .6 joules with function times of .7 milliseconds to 6 milliseconds (see table 8).

4.0 Future Work

4.1 Further development in composition and techniques will be required as the program advances. The first ceramic squib bodies were made from dry pressings. This technique is unsatisfactory for larger quantities. A mold will, therefore, be designed and built to produce these pieces in quantity.

4.2 Testing will continue at Flare-Northern, the objective being a more sensitive powder capable of tolerating 600°F with no ill affects. Bruceton analyses will be conducted using the more favorable appearing mixes.

4.3 During the next 3 months, approximately 550 squibs will be built. These will also be given a preliminary sparking test and loaded with an explosive mix preparatory to testing at Flare-Northern. 50 pieces will be given a preliminary RF test at Franklin Institute.

TABLE 8

Squib No.	Gap Spacing	Resistance K Ohms	Minimum No Fire (Joules)	Resistance (Ohms) After Pulse Test
1030-11-4	.039"	80	.18	80,000 ohms
1030-11-5	.039"	70	.125	65 K ohms
1030-11-17	.039"	85	.18	80 K ohms
1030-11-16	.039"	90	.18	85 K ohms
1030-11-13	.039"	110	.18	100 K ohms
1030-11-6	.036"	100	.18	95 K ohms
1030-11-8	.036"	75	.18	70 K ohms
1030-11-14	.035"	75	.18	65 K ohms
1030-11-10	.035"	110	.32	95 K ohms
1030-11-12	.031"	130	.125	110 K ohms
1030-11-15	.031"	95	.32	90 K ohms
1030-11-7	.030"	95	.125	90 K ohms
1030-11-11	.040"	150	.18	130 K ohms
1030-11-9	.043"	130	.125	110 K ohms
1030-11-18	.086"	75	No Fire (6.25)	70 K ohms
1030-11-19	.090"	95	No Fire (6.25)	85 K ohms
1033-1-1	.067"	110	.18	90 K ohms

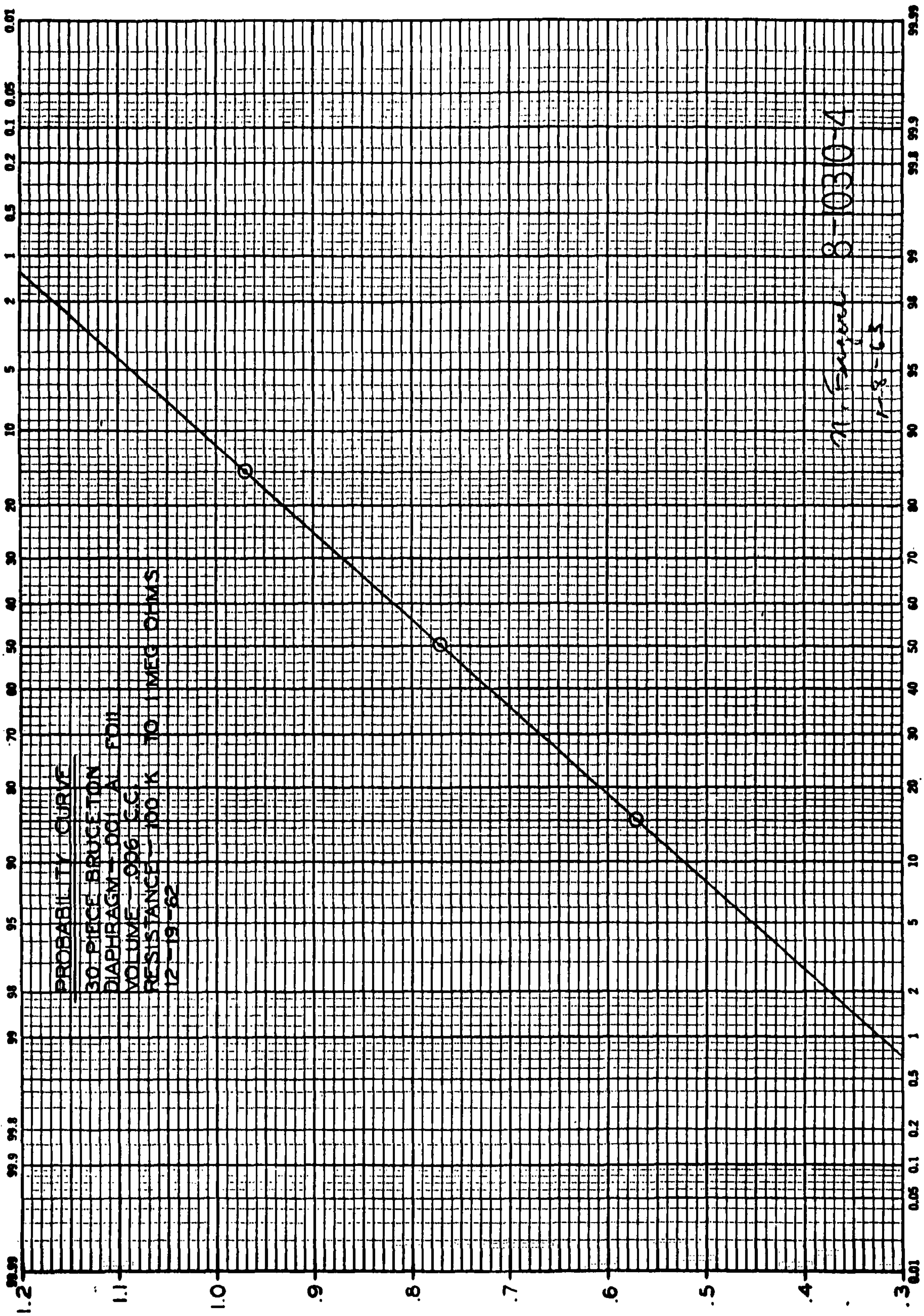
PROBABILITY CURVE
30 PIECE BRUCETON
DIAPHRAGM — .001 AL FOIL
VOLUME — .006 C.C.
RESISTANCE — 100 K TO 1 MEG OHMS
12-19-62

Figure 1

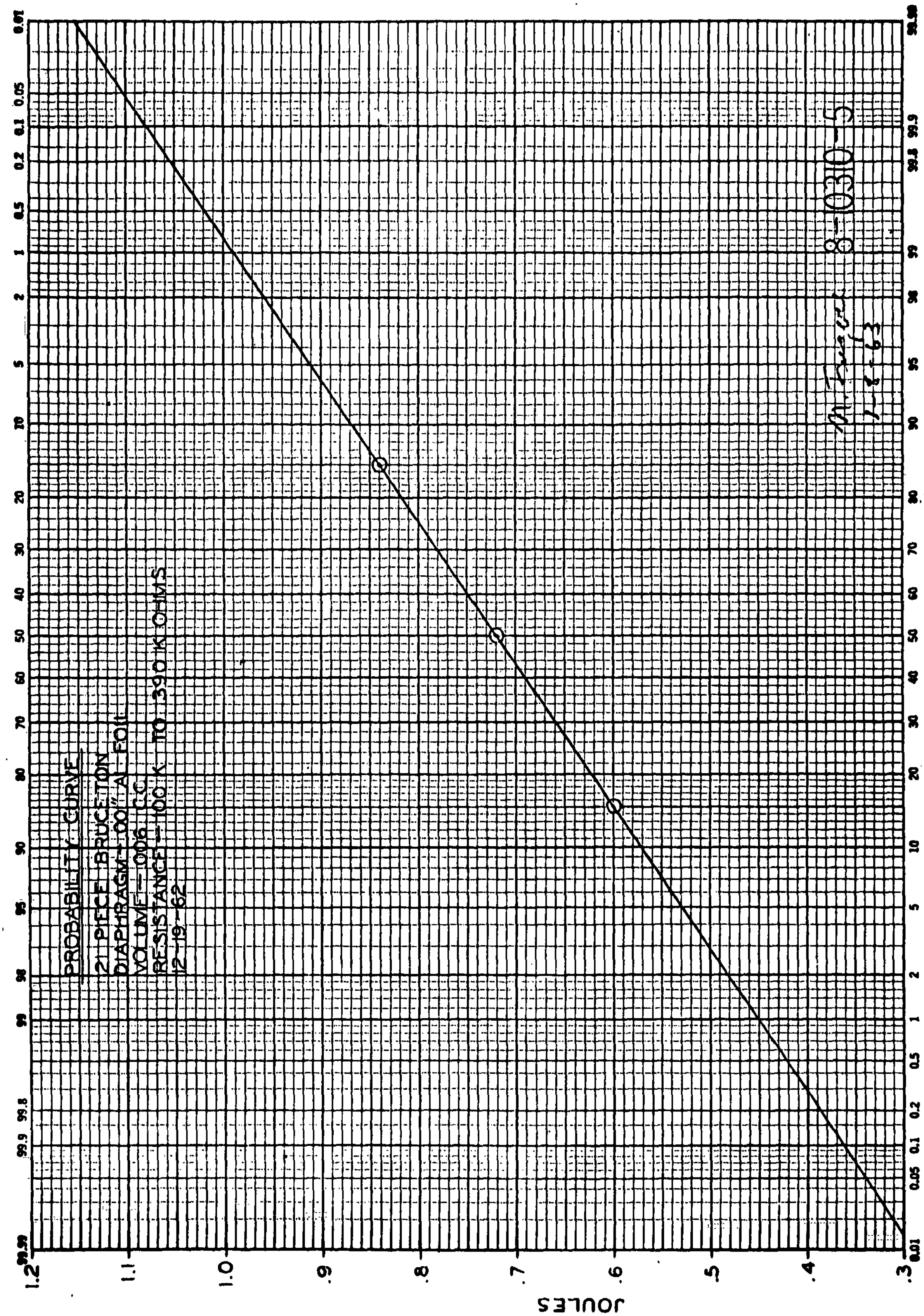
PROBABILITY CURVE
2 PIECE BRUCETON
DIAPHRAGM-.001" AL FOIL
VOLUME-.006 CC
RESISTANCE-100 K TO 390 K OHMS
12-19-62
JOULES
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
8-1030-5

Figure 2

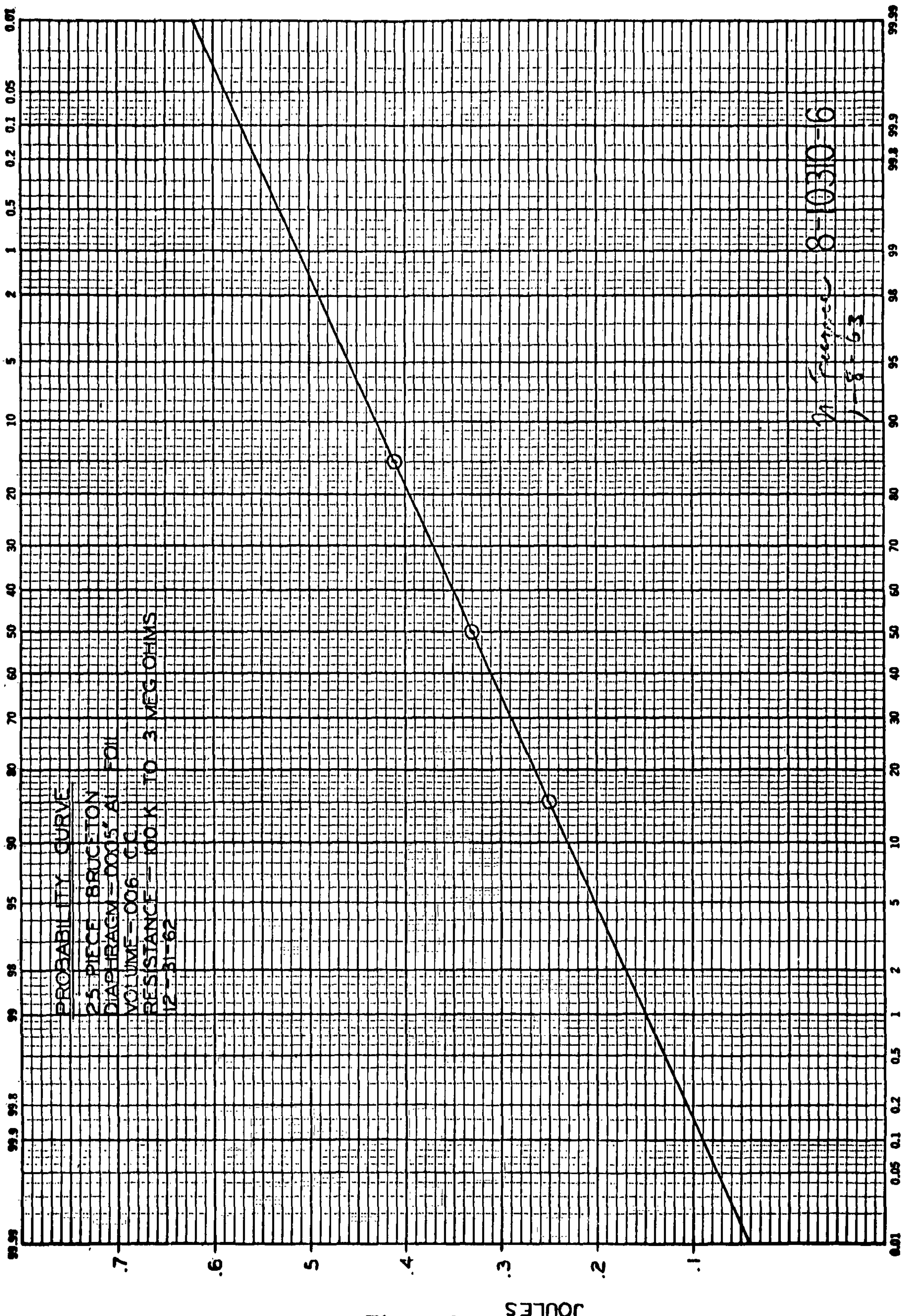
PROBABILITY CURVE
25 PIECE BRUCETON
DIAPHRAGM-.0005" AL FOIL
VOLUME-.006 CC
RESISTANCE-100K TO 3 MEG OHMS
12-31-62
JOULES
8-10310-6

Figure 3

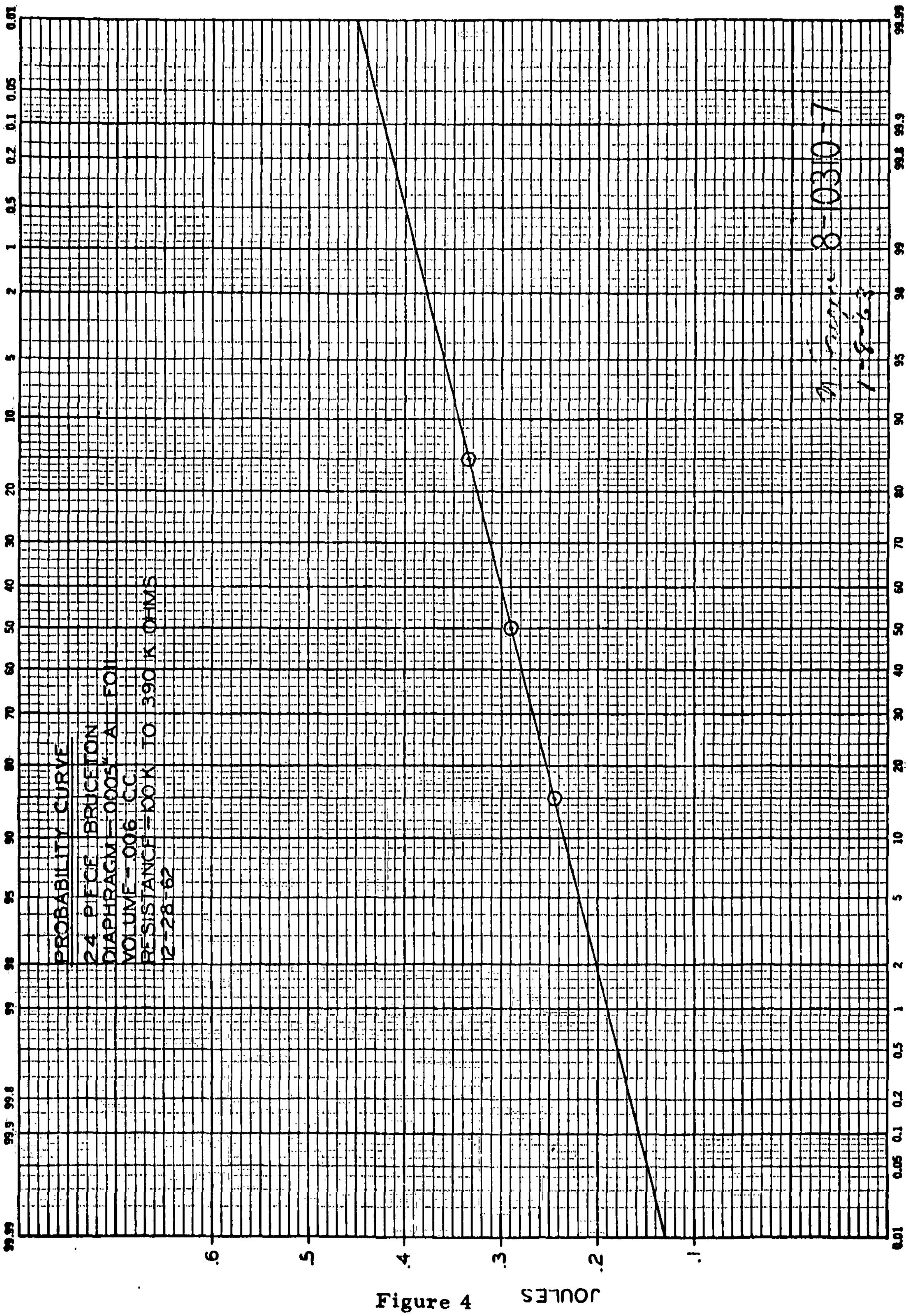
PROBABILITY CURVE
24 PIECE BRUCETON
DIAPHRAGM—.0005" Al FOIL
VOLUME—.006 CC
RESISTANCE—100K TO 390 K OHMS
12-28-62
8-030-7
JOULES
.1
.2
.3
.4
.5
.6

Figure 4

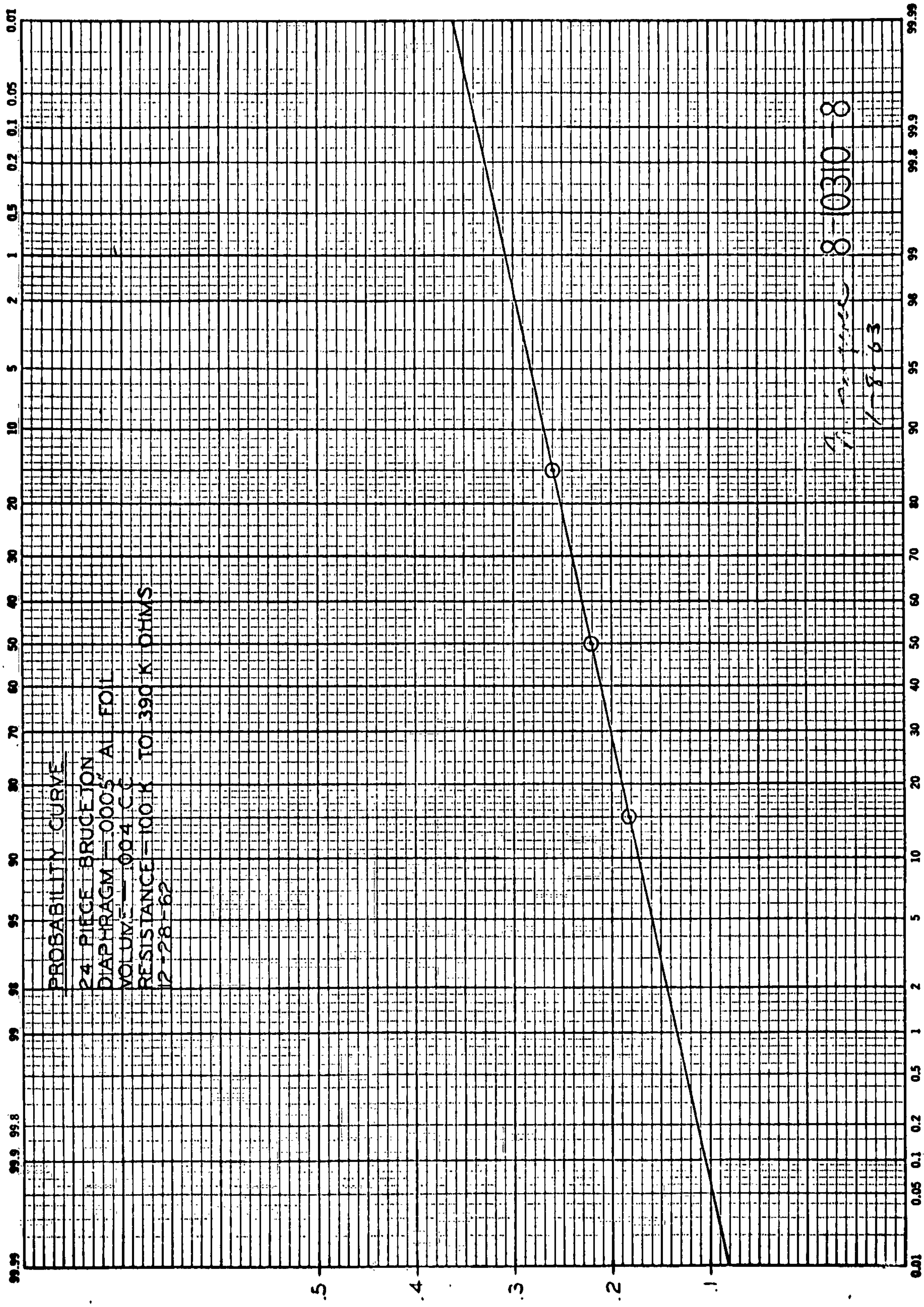

Figure 5 JOULES